INVESTIGATION OF SEVERAL ASPECTS OF LANDSAT 4/5 DATA QUALITY

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Band-to-Band Registration

A second quadrant from the Sacramento, CA scene 44/33 acquired by Landsat-4 during the TDRSS test on August 12, 1983 was tested for its band-to-band registration. The results for Quadrant 1 were reported earlier and showed that all band pairs tested were within allowable tolerances for misregistration. However, there was a discrepancy for those band pairs from the primary and secondary focal planes between this TIPS format scene and the TIPS version of the NE Arkansas scene of August 22, 1982. For bands 3 vs. 5 the Arkansas scene had misregistrations of 0.10±0.03 pixels across-scan and -0.10±0.03 pixels along-scan, whereas the Sacramento scene had 0.17±0.02 pixels across-scan and 0.14±0.02 pixels along-scan. The along-scan discrepancy, particularly, suggested different corrections had been applied. Consequently, it was decided to test Quadrant 4 of the Sacramento scene for consistency with Quadrant 1. The results are shown in Table 1. For convenience, the mean shifts measured in Quadrant 1 are recorded in the last column. These results show that all the measured misregistrations are within 0.03 pixels for similar band pairs between these quadrants and the 95% confidence intervals overlap. Thus, the discrepancy between the Sacramento and NE Arkansas TIPS format scenes is real.

Two Landsat-5 scenes of TM data have been received and tested for band-to-band registration. The Corpus Christi scene from March 6, 1984 had only the first four bands, but a scene of Huntsville, Alabama (20/36) from March 15, 1984 had all seven bands. The Corpus Christi results are shown in Table 2 for Quadrant 1 which was completely over land areas. All the measured mean misregistrations are less than 0.03 pixels. Results for Quadrant 1 of the Huntsville scene are shown in Table 3. Comparison with comparable band pairs in the Corpus Christi scene shows almost identical results--within 0.01 pixels. Band pair 5 vs. 7 is even better registered than in Landsat-4. Band pairs 3 vs. 5 and 3 vs. 7 again show a significant misregistration between the primary and secondary focal planes, as in the early Landsat-4 data. The across-scan misregistration is -0.66 pixels and the 95% confidence interval from -0.68 to -0.63 covers both band pairs. This is more than twice the allowed misregistration of 0.30 pixels and should be corrected as soon as possible. The along-scan misregistration is 0.13 pixels, well within the allowed amount, but it should be corrected also. (A negative shift means that with band 3 as the primary (stationary) band, bands 5 and 7 must be shifted up to be registered.) These results were compared to similar work by General Electric on other scenes using GCP chips; the across-scan results were almost equal and the along-scan results were within 0.05 pixels. Both GE and John Barker at GSFC were informed of these facts.

Interdetector Noise

The goal of the interdetector noise task is to characterize TM interdetector noise with an emphasis on the relationship between gray level and striping. In addition, observation of coherent noise in some bands prompted a characterization of that noise.

A relationship between gray level and striping might be caused by the histogram equalization procedure used to destripe imagery when different noise levels are present in different detectors. The data on A-tapes has been corrected by constructing radiance look-up tables (RLUTs) such that the mean and variance of the gray levels for each detector are equal to the mean and variance of the gray levels for detector 9. If detectors have different levels of additive noise with a mean of zero, i.e. noise uncorrelated with the signal, the variances of the detectors will vary with the variances of the noise. Histogram equalization will force all detector variances to be the same, so that in areas darker than the mean, the noisiest detectors will have higher gray levels than the other detectors, and in areas brighter than the mean, the noisiest detectors will have lower gray levels than the others.

Previously, we examined a uniform 256x256 pixel area in Chesapeake Bay by two dimensionsal Fourier spectrum analysis. We found striping was present in all bands and coherent noise (along-scan) was present in TM bands 1-4. We found that individual detectors in a given band had different gray level variances, particularly in bands 1 and 7, and we assumed this was due to different amounts of noise in individual detectors. We used the measured variances in a simulation of the effects of the histogram equalization procedure. Random Gaussian noise with zero mean and with variances equal to the variances of the 16 TM band 7 detectors was added to 16 constant images (gray level=45) and the images combined to simulate a constant, but noisy, band 7 image. The variances ranged from 0.8 to 4.4. Histogram equalization was applied to make all means and variances equal to those of detector 9. Preliminary Fourier analysis showed that increased striping existed in the "corrected" image, similar in pattern but not as great in magnitude as the real data.

A 512x512 pixel area in a uniform area of the Pacific Ocean from the San Francisco Scene of December 31, 1984 was corrected for the pixel offsets present in A-tape format. Fourier analysis showed identical along-scan noise frequency components as in the Chesapeake Bay scene but with better definition due to the larger image size. This image is being used to develop procedures for generation of locally modulated noise images to better characterize the noise components.

Modulation Transfer Function

The MTF analysis of the San Mateo Bridge using data from the San Francisco scene of December 31, 1982 has been reported earlier. In the current period, similar analyses of that bridge using data acquired on August 12, 1984 was completed. The results are reported

in Professor Schowengerdt's Progress Report which is attached to and made part of this report. The August data permitted analysis of all bands (except the thermal band) because of the increased contrast. The effective instantaneous field of view (EIFOV) was calculated from the MTF results. The EIFOVs of the winter data were about 41 meters except for band 3 at 33.6 meters. These figures are higher than the nominal IFOV (30 meters) but they include all effects (instrument parameters, sampling, atmosphere). The EIFOVs of the summer data are higher yet: about 10% higher for bands 4, 5 and 7 and are about 50 meters for bands 1, 2 and 3. Schowengerdt suggests part of the explanation of the EIFOVs for bands 1-3 may rest on the poor contrast involved.

Initial results were obtained for the two image analysis where portions of low altitude flightlines (7 meter resolution) of high spatial frequency targets were registered with the TM data of the same target. The results were quite noisy, a characteristic of the method. Profiles of the two dimensional MTF were extracted at four azimuth angles. Those along ±45 degrees yielded more reasonable results but the calculated EIFOVs were higher still, 55 and 65 meters.

TABLE 1

Summary statistics for band-to-band registration of Thematic Mapper band combinations for the Sacramento scene of August 12, 1983 (Quadrant 4) in TIPS format. All correlation blocks with the correlation coefficient <0.6 were discarded (<0.3 for bands 6 vs. 7). The unit of misregistration (shift) is pixels.

TM Bands	Shift Direction	Number of Blocks	Mean Shift	Std. Dev.	95% Confid. Interval for Mean Shift	Mean Shift Quad 1
3 vs 1	Across-scan	189	-.05	.10	-.04 to -.03	-.04
	Along-scan	189	-.04	.07	-.05 to -.03	-.05
3 vs 2	Across-scan	191	.02	.09	.00 to .03	.01
	Along-scan	191	-.02	.05	-.03 to -.01	-.03
3 vs 4	Across-scan	83	-.01	.25	-.06 to .04	.01
	Along-scan	83	-.01	.22	-.06 to .04	.02
3 vs 5	Across-scan	161	.16	.14	.14 to .19	.17
	Along-scan	161	.12	.14	.09 to .14	.14
3 vs 7	Across-scan	167	.10	.12	.08 to .12	.11
	Along-scan	167	.11	.10	.10 to .13	.14
5 vs 7	Across-scan	197	-.05	.08	-.06 to -.04	-.05
	Along-scan	197	.00	.07	-.01 to .01	-.01
6 vs 7	Across-scan	130	.16	1.47	-.09 to .41	.29
	Along-scan	130	.02	1.21	-.19 to .23	-.03

TABLE 2

Summary statistics for band-to-band registration of Thematic Mapper band combinations for Quadrant 1 of the Landsat-5 Corpus Christi, TX scene of March 6, 1984 in TIPS format. All correlation blocks with the correlation coefficient <0.6 were discarded. The unit of misregistration (shift) is pixels.

TM Bands	Shift Direction	Number of Blocks	Mean Shift	Std. Dev.	95% Confid. Interval for Mean Shift
3 vs 1	Across-scan	174	-.03	.06	-.03 to -.02
	Along-scan	174	.01	.07	.00 to .02
3 vs 2	Across-scan	180	-.03	.05	-.03 to -.02
	Along-scan	180	.00	.06	-.01 to .01
3 vs 4	Across-scan	157	-.02	.15	-.05 to .00
	Along-scan	157	-.03	.12	-.05 to -.01

TABLE 3

Summary statistics for band-to-band registration of Thematic Mapper band combinations for the Landsat-5 Huntsville, AL scene of March 15, 1984 (Quadrant 1) in TIPS format. All correlation blocks with the correlation coefficient <0.6 were discarded (<0.3 for bands 6 vs. 7). The unit of misregistration (shift) is pixels.

TM Bands	Shift Direction	Number of Blocks	Mean Shift	Std. Dev.	95% Confid. Interval for Mean Shift
3 vs 1	Across-scan	172	-.03	.06	-.04 to -.02
	Along-scan	172	.00	.07	-.01 to .01
3 vs 2	Across-scan	191	-.04	.05	-.04 to -.03
	Along-scan	191	.00	.05	-.01 to .00
3 vs 4	Across-scan	126	-.02	.09	-.04 to -.01
	Along-scan	126	-.03	.10	-.05 to -.02
3 vs 5	Across-scan	179	-.65	.15	-.67 to -.63
	Along-scan	179	.13	.12	.11 to .14
3 vs 7	Across-scan	186	-.66	.14	-.68 to -.64
	Along-scan	186	.12	.12	.10 to .13
5 vs 7	Across-scan	193	-.01	.05	-.01 to .00
	Along-scan	193	-.03	.06	-.04 to -.02
6 vs 7	Across-scan	57	.03	2.63	-.65 to .72
	Along-scan	57	-.10	2.13	-.65 to .46